INTEGRATION OF GROUP TECHNOLOGY AND MATERIAL REQUIREMENTS PLANNING FOR EFFICIENT LOT SIZING

by

JOYDIP GHOSH

DEPARTMENT OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

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JOYDIP GHOSH

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CERTIFICATE

This is to certify that the work entitled, 'Integration of Group Technology and Material Requirements Planning for Efficient Lot Sizing', has been carried out by Joydip Ghosh, under our supervision and has not been submitted elsewhere for the award of a degree.

(Dr. Kripa Shanker)
Professor
Industrial and Management Engg.
Indian Institute of Technology
Kanpur - 208016

(Dr. M.K. Muju)
Professor
Mechanical Engg. Dept.
Indian Institute of Technology
Kanpur - 208016

April, 1987.

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ABSTRACT

In the present work an attempt has been made to integrate some significant benefits of group technology approach with the lot sizing of material requirements planning. In a modern discrete part manufacturing enviornment it is very usual to have a number of parts having similar attributes. If these similar parts are put into one part family and then considered for further operations, various costs involved can be economized.

Two of the clustering algorithms, claimed to be most efficient among the many available ones have been used to cluster a part attribute matrix for the purpose of generating part families. The model is capable of handling a known number of parts having a known number of maximum attribute varieties.

In the MRP module the parts belonging to the highest level in the product structure are grouped into some families and are handled by the standard MRP computation technique with Silver- Meal heuristics as the lot sizing technique. The proposed method of considering all the parts belonging to the same family simultaneously helps in reducing various costs, e.g., the total set-up cost, the data handling cost, etc. for the whole family.

The performance of the software is checked by several trial runs with different inputs, i.e. product structure and master production schedule and it is concluded that the approach used can be an acceptable efficient method.

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CHAPTER I

INTRODUCTION

In any manufacturing system, the basic inputs, such as manpower, material, methods, information and facilities, are transformed into finished products. With the improvement in technology and capacity of information processing, the productivity range of manufacturing systems also has been considerably improved. The latest trend is towards completely automated manufacturing systems ensuring high system productivity. The commercial availability of computers in the mid-1950s ushered in a new era of business information processing, with a profound impact of the new technology on the conduct of operations. Nowhere has this impact probably been greater, at least potentially, than in the area of manufacturing logistics, i.e., materials planning, inventory management and production planning, etc.

In the area of manufacturing materials management, the most successful innovations are embodied in what has become known as material requirements planning (MRP) systems.

In a modern automated batch production enviornment, various components operated on usually have some similarities in different attributes. During various manufacturing operations on such similar parts it is observed quite often that the set up of the machine tools, tools, coolants, jigs and fixtures, material handling systems, measuring and inspection systems, etc., remains common for all of them. Group Technology exploits this feature by grouping all such similar parts into same family. This

assures a substantial reduction in the set-up costs involved in the manufacturing of all such parts. In the present approach such part family approach is integrated with MRP computations to get similar benefits and economy. Moreover by handling the parts in families, instead of individual parts the huge data handling involved in MRP can also be reduced.

1.1 Computer Aided Manufacturing Systems:

Computer Aided Manufacturing (CAM) can be defined as the use of computer systems to plan, manage, and control the operations of a manufacturing plant through either direct or indirect computer interface with the plant's production resources (Groover [7]).

The applications of computer-aided manufacturing fall into two broad categories:

i) Computer monitoring and control-These are the direct applications in which the computer is connected directly to the manufacturing process for the purpose of monitoring and controlling the process.

ii) Manufacturing support applications- These are the indirect applications in which the computer is used in support of the production operations in the plant, but there is no direct interface between the computer and the manufacturing process.

In the second category the computer is used 'off-line' to produce control signals related to plans, schedules, forecasts, instructions and informations.

Material requirements planning is such an example of CAM for manufacturing support. Here the computer is used to determine when to order raw materials and purchased components, and how many should be ordered to achieve the production schedule.

The production activity of different firms involved in production can be divided into four broad categories:

i) Continuous-flow processes
ii) Mass production of discrete products
iii) Batch production
iv) Job shop production

There is always some overlapping of the categories in practical conditions. In CAD/CAM environment,zone of interest lies in the two medium range production policies, i.e. Mass production of discrete products and Batch production.

1.2 Introduction to Material Requirements Planning:

Material requirements planning is a computational technique that converts the master production schedule for end products into a detailed schedule for the raw materials and components used in the end products. The detailed schedule identifies the quantities of each raw material and component item. It also tells when each item must be ordered and delivered so as to meet the master schedule for the final products (Groover [7], Orlicky [18]).

With the improvement of the computer-aided inventory management systems, the true interrelationship and behaviour of different items constituting the manufacturing inventory becomes visible and reveale the causes of inadequacies of many traditional methods. The successful users of the new systems reduced their inventories and improved delivery services at the same time. This is how the material requirements planning,which is essentially a computer aided inventory control and production control system, took the lead,

The principles of material requirements planning, the processing logic and the methods of using the system are described in chapter IV.

1.3 Introduction to Group Technology:

The term group technology (GT) applies to the range of manufacturing processes, consisting of mass production of discrete parts and batch production in discrete lots.

Group technology is a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in manufacturing and design. Similar parts are arranged into part families (Groover [7]).

An example can be taken of a plant producing 3,000 different part varieties. It is possible to group the vast majority of these parts into 20 or 30 major and distinct families on the basis of their similarities in design and/or manufacturing characteristics. Now the whole manufacturing process for the

3,000 parts becomes the process for 20 or 30 families of parts, leading to the reduction in set-up times, set-up costs, lower in-process inventories, better and efficient scheduling, improved tool control and the use of standardised process plans.

Arranging the different parts into part families constitutes a major portion of GT. A 'part family' is a collection of parts which are similar either because of geometric shape and size, or because similar processing steps are required in their manufacture. The biggest obstacle in changing over to group technology from a traditional production shop is the problem of grouping parts into families. There are various approaches in solving the problem. Current manufacturing systems technology imposes some limits on shapes and technological properties of parts, which emphasises on grouping parts into families.

There are several approaches available for grouping parts into part families.

Classification and Coding Systems:

One of the basic tools in group technology for parts grouping has been a classification and coding system. This enables the description of parts based upon their geometrical shape, dimensional accuracy,material,etc. Some of the most widely used classification and coding systems are as follows:

i) BRISH-BIRN (U.K.)- based on four to six digit primary code and a number of secondary digits.

ii) DCLASS (USA)- a software based system without any fixed code structure.

iii) CODE- MDSI (USA)- an eight digit code.

iv) MICLASS (The Netherlands)- a twelve to thirty-two digit code.

v) OPITZ (West Germany)- a five digit primary code with a four digit secondary code.

vi) TEKLA (Norway)- a twelve digit code.

Out of the mentioned methods the OPITZ coding and MICLASS coding systems are most popular.

The other approaches for data collection and solving the part families problem are

Pattern recognition based parts grouping

Selective Approach

p-median Formulation

Matrix Formulation etc

etc.

The above mentioned approaches are discussed in details in chapter III.

1.4 Integration of GT and MRP:

In MRP the master production schedule (MPS) for the end products in converted into a detailed schedule for raw material and components used in the end products. The concept of MRP is relatively straight forward. It is only the sheer magnitude of the data to be processed, which makes the application of the

technique complicated. Each of the end products, planned in the master production schedule, may contain thousands of individual components. These components are produced out of raw materials, some of which are again common among the components. For example we can use the same washer for different products and different types of washers may be produced out of the same sheet steel. The basic components are assembled into simple subassemblies. Then these subassemblies are put together into more complex assemblies- and so forth, until the final assembly is obtained. For each step of production a lead time has to be considered. All of these factors must be incorporated into the MRP computations. Hence several attempts have been made to minimize the large data handling and various costs as well.

If we consider the similarities among the basic level components, it is very likely that, a large number of components will have similarities in their design and manufacturing attributes. In GT the parts having similarities are identified and then put in some part families which are different from each other. The part families are then considered for different manufacturing operations. This ensures a great reduction in the production planning and production control activities. This ensures a great reduction in the set-up cost for each of the members of the family also, as the set-up for all the members in a family are almost same due to their similarity in the manufacturing attributes. In such an enviornment the set-up cost is considered for the families instead

of each of the parts in the families.

In the present work an effort is made to integrate the above mentioned benefits of GT in MRP. The individual parts at the highest level of product stіucture, i.e. which are to be produced in the shop floor, can be very effectively grouped on the basis of their manufacturing and design attributes, in the same way as in GT. Now we consider the parts in the same family together for further MRP computations. This definitely assures a much less quantity of data to be handled. The basic advantage of the proposed method is its capability to reduce the set up cost for all the members in the family,as here all the MRP decisions are basically made on the basis of the set-up cost for the families. This certainly helps in developing an improved lot sizing method based on the families. The proposed technique is discussed in details in chapter IV.

CHAPTER II

LITERATURE SURVEY AND OBJECTIVE OF THE PRESENT WORK

2.1 Literature Survey:

The literature consulted during the present work can be divided into two broad categories:

Literature survey for GT family formation techniques.

Literature survey for MRP and lot sizing techniques.

2.1. a) Literature Survey for GT Family Formation Techniques:

From the point of view of production, the approach of GT is to form families of components and group the machines into cells, each cell generally takes care of one family. Extensive research work has been done on this objective for a long period. The technique was probably in proper use in Europe even before World War II, but the first published work in this field appeared only in 1959, in the USSR [Mitrafanov, 1959] Mitrafanov, one of the pioneers of GT advocated the composite component approach. This method is applicable to small parts having only a few operations, e.g. bushes, covers, small shafts etc. In this method the family of similar parts is formed by examining the drawings and then a hypothetical composite component is drawn, which incorporates all the features found in the various components in the family.

In the route card analysis approach, the information given in the route cards are used in order to form part families. Here the objective is to form machine cells and component families in such a way that all the benefits of GT, like faster through-put, reduced material handling, reduced work in process etc., can be derived to the fullest possible extent. One of the earliest analytical methods suggested was production flow analysis (PFA), a technique developed by (Burbidge [3]). Another mathematical cluster analysis model was introduced by McAuley [13] for the similar analysis, but it has various disadvantage of producing machine-disjoint cells. El-Essawy [4] developed an approach for solving the problem, called component flow analysis (CFA). But the papers by El-Essawy and Torrance do not give any meaningful details of how the analysis is to be done.

Classification and coding systems has been one of the basic tools in GT for parts grouping. This enables the description of parts based upon their geometrical shape,dimensional accuracy, material etc. A number of classification and coding systems are available. Which are already mentioned in chapter I.

Another approach utilizes pattern recognition as the basis of part grouping [10], [5]. This method is discussed in details in chapter III.

In selective parts grouping, instead of considering the geomettical and technological parameters, some other attributes in reference to manufacturing enviornment are considered.

Clustering analysis is a tool which can be applied to formulate and solve the part families problem. From among the available clustering analysis formulations, two of them are considered.

i) p-median formulation

ii) matrix formulation

There are different algorithms available under the second category which converts the part-attribute matrix into clustered matrix, to make part families clearly visible.

Depending on the way these operations are performed, the following algorithms are available

a) bond energy algorithm [McCormick et al, 12]

b) shortest spanning path algorithm [Slagle et al,21]

c) Maching algorithm [Bhat and Haupt,2]

d) rank order algorithm [King, 8]

e) an integer programming approach [Kusiak, 11]

f) rank energy algorithm [Kusiak,10]

g) a hierarchical approach [Stecke,22]

Most of the above mentioned formulations are suitable for flexible manufacturing systems enviornment. Kusiak [10] suggests that the part families problem can be modelled as a p-median problem or the advantage of the special structure of clustering matrices (i.e. low density, large number of rows and small number of columns) can be taken and the problem can be solved by rank energy algorithm.

2.1. b) Literature Survey for MRP and lot Sizing Techniques:

In recent years a lot of research work has been done on the material requirements planning, one of the most important component of the computer-integrated production management system (CIPMS). Several books have been written on this subject, for example [Orlicky, 18].

MRP has expanded to mean more than material requirements planning. The term 'MRP II' is used [Wight, 25] to represent manufacturing resource planning, a system for planning and controlling the operational, engineering, and financial resources of manufacturing firms. In his book, Wight defines four classes of MRP users.

Discrete lot sizing, i.e. the problem of determining an optimal feasible production policy by generating production quantities that equal the net requirements in an integral number of consecutive planning periods is one of the important planning factors of MRP.

There are ten most widely recognized approaches to lot sizing of which seven are discrete lot sizing techniques:

1. Fixed order quantity
2. Economic order quantity (EOQ)
3. Lot for lot
4. Fixed period requirements
5. Period order quantity (POQ)
6. Least unit cost (LUC)

7. Least total cost (LTC)
8. Part-period balancing (PPB)
9. Wagner-Whitin algorithm (W-W) [24]
10. Silver-Meal heuristics [19]

The first two of the above are demand rate oriented, the others are discrete lot sizing techniques, because they generate order quantities that equal the net requirements in an integral number of consecutive planning periods. In addition to these recently, modified versions of EOQ and least total cost (LTC) have been suggested [Mitra et al, 14]. Another much simpler solution procedure giving optimal solution is developed on the basis of incremental cost approach (ICA) [Naidu and Singh, 16].

Reuvenkarni and Yaakov Roll [20] suggested a heuristic algorithm for the multi-item lot-sizing problem with capacity constraints.

A multi-objective linear programming approach [Gonzalez and Reevs, 26] gives a satisfying solution for the given priority structure, but is found unsuitable for large number of products and time periods.

In the present work, the silver-meal heuristic is chosen as this huristic is best suitable for a varying demand enviornment and very simple to emplement as well.

2.2 Objective and Scope of Present Work:

With the techniques of MRP lot sizing gaining more and more importance both in industry and research, there is certainly

the need of some research work in this field. In the automated manufacturing concept the use of MRP is one of the most important components.

The idea behind the proposed method comes from the basic benefits assured by modern group technology approach. Grouping of component parts into part families results in high efficiences. These efficiencies are achieved in the form of reduced set-up times, better scheduling, lower in process inventories, improved tool control, use of standardized process plans, etc. Now some of these benefits can be incorporated in MRP very effectively.

In MRP, the direct components or the basic level components are considered for the current study. In any product structure for some complicated assembly type of job, e.g. motor vehicles, etc. will have a large number of direct components which are to be manufactured in the shop floor by batch production.

To determine the effective lots for such batch production, is a field of importance for manufacturing firms. If all the direct (n-level) components are grouped into part families on the basis of their manufacturing attributes, we can see there is a perceptible reduction in the various costs. This on the other hand essentially reduces the huge amount of data handling involved with MRP computations.

So far the available systems have not viewed the lot sizing in MRP from this point of view. Hence in the current work a method is proposed to have a new and effective lot

sizing technique.

2.3 Organization of The Thesis:

The thesis attempts to cover some useful and important information for both the fields:GT and MRP.

Chapter III presents the part family formation technique of GT. Few standard approaches are described in a nutshell. The rank energy algorithm, and Bhat and Haupt algorithm are discussed elaborately.

Chapter IV consists of some detailed introduction to MRP followed by the proposed technique of integration of GT and MRP. This covers the part family formation using the rank energy algorithm and MRP lot sizing of the part families by Silver-Meal heuristic.

Chapter V deals with the implementation aspect in details. This describes the whole technique as several modules and their functions towards the working of the technique.

Chapter VI deals with the experimentation with the system. The results of the experiments are also given in this chapter along with output analysis.

The last chapter presents the conclusions arrived through this work, and points to further development in the related field.

Appendix A gives a special coding system.

CHAPTER III

PART FAMILY FORMATION IN GROUP TECHNOLOGY

The most important part in GT is arranging the different parts into part families. Some of the conventional methods are already introduced in chapter I and II. In the following section some modern and efficient algorithms are discussed.

3.1 Various Approaches for Part Family Formation:

Out of the recently developed tools for part grouping, the clustering analysis is one which can be effectively applied to formulate and solve the part families problem.

From among the available clustering analysis formulations, the following two are reported to be of significance:

i) p-median formulation

ii) matrix formulation

3.1.1 p-median Formulation:

This formulation is based on a clustering model discussed by Arthanari and Dodge [1]. The formulation is carried under the following constraints:

Each part must belong to exactly one part family, the number of part families is specified, the part family for an item is formed only if the corresponding element is a median, the last constraint ensures integrality (for more detailed discussion of the p_median problem, Arthanari and Dodge [1] can be consulted. One of the most important characteristic features of the above

formulation is that the number of part families is a parameter. It may be very useful in the case when the number of part families is imposed by some other factors, for example, standard fixtures or standard robot grippers etc. p-median problem has been solved by Kusiak [11].

3.1.2 The Matrix Formulation:

The matrix formulation has two basic differences from the integer programming formulation, i.e.

a) it is not as mathematically rigorous

b) the number of the part families is a result of clustering.

The matrix formulation of the part families problem can be presented in the form of a matrix X.

$$X = [x_{ij}] = \begin{matrix} x_{11} & x_{12} & \cdots & x_{1z} \\ x_{21} & x_{22} & \cdots & x_{2z} \\ \vdots & & & \\ x_{n1} & x_{n2} & \cdots & x_{nz} \end{matrix}$$

where x_{ij} is the value of attribute j for part i.

Each row of matrix X represents a vector of attribute values for a component. The solution of part families problem is based on rearranging rows and columns in matrix X, so that

part families (clusters) can be visible. The clustering of parts is illustrated in example 1.

Example 1:

Given a matrix A of attribute values for four parts, a matrix A' is to be found with clustered part families

$$A= \begin{array}{cccc} & 1 & 32 & 3 \\ 1 & 1 & 0 & 0 \\ 2 & 0 & 1 & 1 \\ 3 & 1 & 0 & 0 \\ 4 & 0 & 1 & 1 \end{array} \qquad A'= \begin{array}{cccc} & 1 & 2 & 3 \\ 1 & 1 & 0 & 0 \\ 3 & 1 & 0 & 0 \\ 2 & 0 & 1 & 1 \\ 4 & 0 & 1 & 1 \end{array}$$

Two clusters of ones can be easily seen in matrix A'.

Matrix A' is obtained from matrix A by a number of row and column interchanges. Depending on the way these rearrangements are performed, the following algorithms have been developed.

a) Bond Energy Algorithm :

This algorithm has been developed by McCormick et al [12]. The purpose of this algorithm, as mentioned by the authors, is to identify and display natural variable groups and clusters that occur in complex data arrays. These tasks are accomplished by permuting the rows and columns of an input data array in such a way as to push the numerically larger array elements together.

Though this algorithm has got a number of applications, the basic disadvantage is its computational complexity ($O(nm^2+n^2m)$), and hence difficulty in industrial applications.

b) Shortest Spanning Path Algorithm:

This algorithm devised by Slagle et al [21] is a clustering and data reorganizing algorithm based on the concept of the shortest spanning path of a graph given.

The concept of shortest spanning path is as follows, a spanning path of a connected graph (graph having paths between any pair of points, called nodes) is a path in the graph that contains all nodes of the graph. The shortest spanning path of a graph G is a spanning path of which the weight is minimum among all spanning paths of G. (for more detailed discussion [21] can be referred .

The concept of shortest spanning paths can be conveniently used in both cluster analysis and data reorganization. Though this technique is comperatively simpler, the computational complexity is high in this case also.

c) Rank Order Algorithm:

This algorithm converts a part attribute matrix, in binary form, into a block diagonal form, if one exists, in only two iterations.

King [8] showed that the patterns of row entries are read as binary words and they are ranked in reducing binary

value order. This then permits the rows to be rearranged in accordance to the rank order. The same procedure can be repeated on the columns as well. This whole process may be continued for rows and then columns until no further rearranging of rows and columns is possible, at which point a block diagonal form will be produced, if one exists. This procedure has a computational complexity of cubic order, namely $O(m^2n+mn^2)$, where m and n are number of rows and columns respectively. Hence its application is also limited.

In the following section the two algorithms used in the present work are described in details.

3.2 The Bhat and Haupt Algorithm:

This algorithm also known as matching algorithm was developed by Bhat and Haupt [2].

The three main general steps of this algorithm can be described as follows. First, determine a scheme for reordering the rows and columns for the matrix array such that the permuted array of coefficients appear in clustered form. Second, evolve a criterian on the basis of which the clustered data can be identified in a meaningful way. Third, the two aforementioned steps be carried out at minimum computational cost.

This algorithm has similarity with the bond energy algorithm and shortest spanning path algorithm, but the matching

algorithm reduces the required computations by a factor of n for row ordering and m for column ordering for a m x n matrix.

a) Matching Concept:

The matching between two rows can be defined as follows. The rows of the matrix

$$A = \begin{matrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 \end{matrix}$$

have maximum match (there are six matchings). On the other hand, the rows of matrix B, where

$$B = \begin{matrix} 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 \end{matrix}$$

have maximum mismatch (there are six mismatchings or zero matchings). This criterion is exploited in the matching algorithm to find a clustering structure for a given matrix.

Depending on the zero-nonzero entries and their interpretation with regard to the problem, weights are assigned to different entries to realize clusters.

b) Matching Algorithm:

The steps of the matching algorithm can be stated as follows

Step I: From an m x n matrix array A compute the m x m array $A* A^T$ ($A^T* A$ forms the n x n array for column ordering). The asterisk designates a matching count between the rows of A and the columns of A^T; $A* A^T$ is a square symmetric matrix of

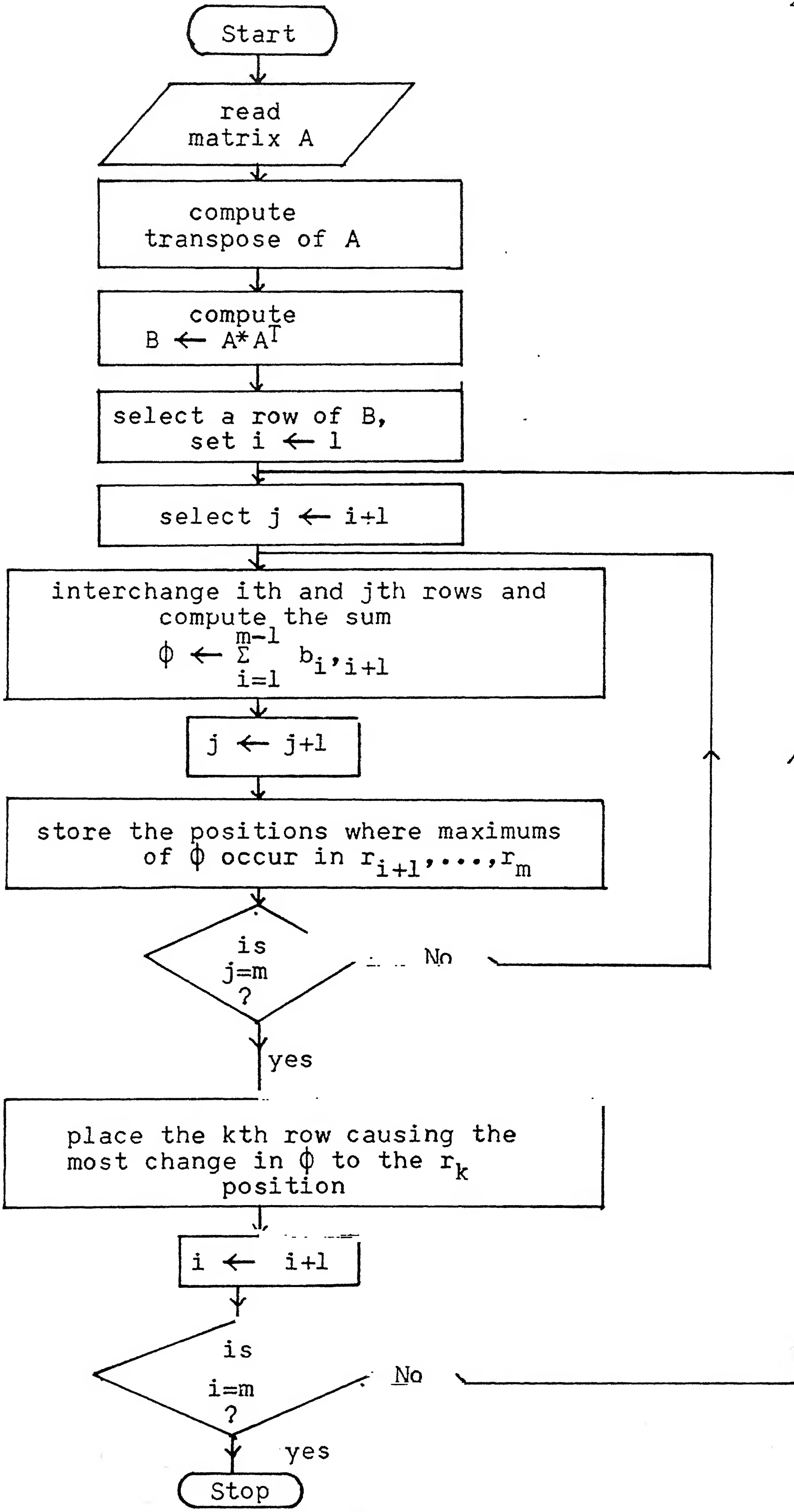


Fig.3.1 Flow chart for Matching Algorithm

size m x m where the (i,j)th entry represents the number of matchings between the rows i and j of the matrix A.

Step 2: Select one of the m rows of $A*A^T$ arbitrarily; set i = 1.

Comment: In Steps3-6 select one out of the remaining m-1 rows that match best with row i. Step 7 repeats this procedure until all the m rows are ordered.

Step 3: Select j = i +1.

Step 4: Try placing the jth row in each of the (i+1) positions. Compute the sum $\phi = \Sigma_{i=1}^{m-1} b_{i,i+1}$, where $B = A*A^T$ for each case and retain the maximum and the corresponding location. Let the maximum be ϕ for the position r_j among (i+1) positions (the computer implementation calculates only the change in ϕ).

Step 5: j=j+1 and repeat Step 4 until j=m. The corresponding maximums of ϕ occur at $r_{i+1} \ldots r_m$.

Step 6: Place the row $k, i+1 \leq k \leq m$, which caused the most change in Steps 4 and 5, in its corresponding location r_k, i.e., maximum ϕ value is obtained when the kth row is placed in the position r_k.

Step 7: i = i+1, repeat Steps 3-7 until i=m. Repeat the above steps for the columns.

Step 8: End.

The matching algorithm is one of the most efficient algorithms for solving the clustering problems. The computational complexity of this algorithm is much less as compared to other similar algorithms.

In the present work a software implementation is done for this algorithm. The details of the implementations are discussed in chapter V.

3.3 The Rank Energy Algorithm:

Taking into account the modern automated manufacturing enviornment, a class of algorithm is needed which would fulfill the following requirements:

a) generate good quality solutions to the part families problem in an acceptable time;

b) be easy to implement in industry.

The matching algorithm, in many cases, fulfils the first above requirement. However, its biggest disadvantage is in a relatively complex logic which might not be acceptable in the industries.

The rank energy algorithm takes the advantage of the features contributing to computational efficiency of the matching algorithm and the procedure of interchanging rows and columns of matrix $A*A^T$ were made easy to implement. This algorithm has taken some of the features of the King's algorithm.also.

The algorithm involves the following steps:

Step 0 : Calculate matrix $B = (A*A^T)$.

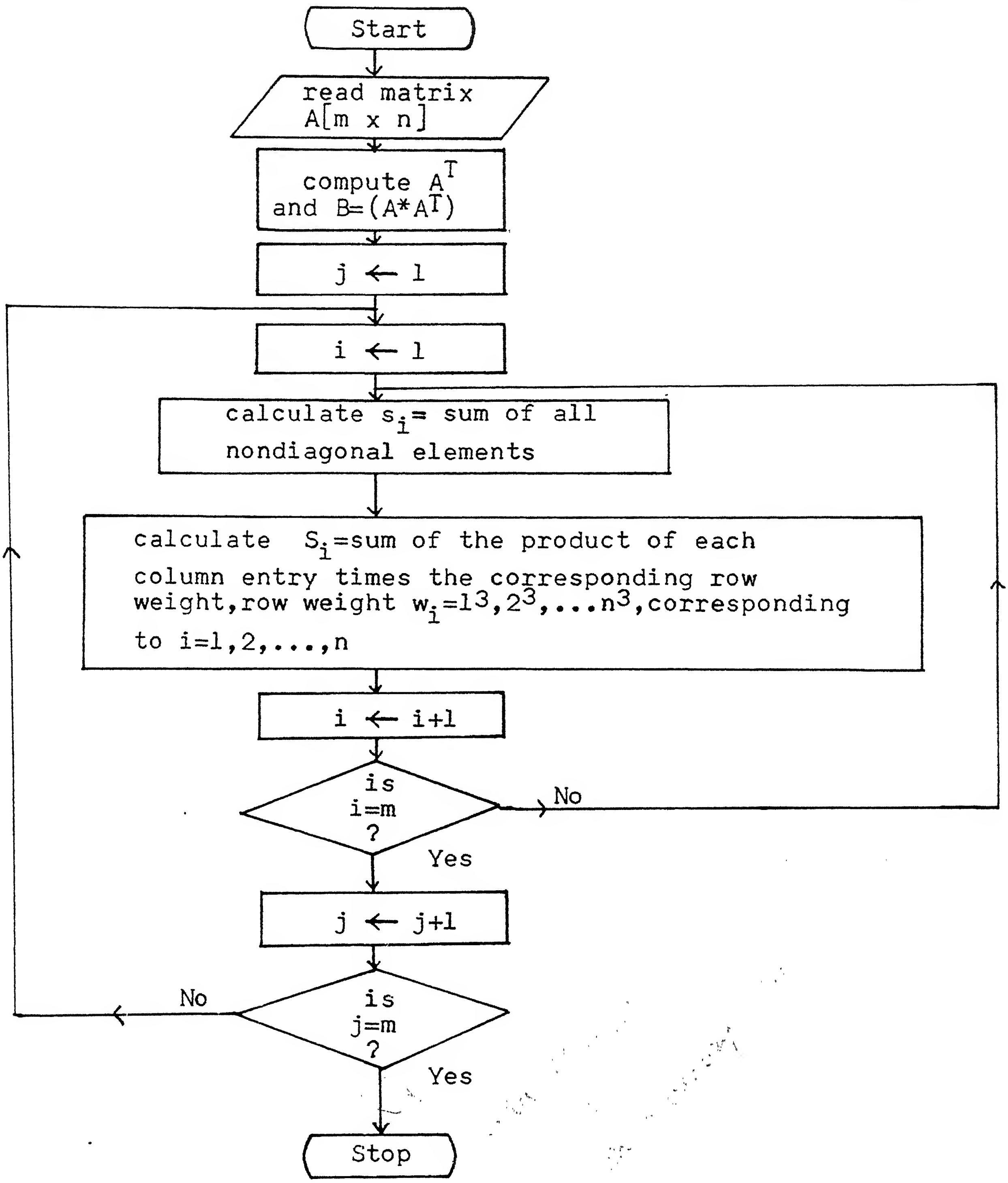


Fig. 3.2, Flow chart for Rank Energy Algorithm.

Step 1: For each column of matrix B, calculate sum s_i, $i=1, \ldots, n$ of all non-diagonal elements

Step 2: For each column of matrix B,calculate sum S_i,$i=1\ldots, n$ of the product of each column entry times the corresponding row weight w_i,$i=1,\ldots,n$.

Step 3: Order sums $s_1, s_2, \ldots, s_n$ in decreasing sequence. If all the ordered values $s_{(1)}, s_{(2)}, \ldots, s_{(n)}$ are distinct, go to step 5; otherwise go to step 4.

Step 4: Order sums $S_{(i)}$; $(i)=(i_1),(i_2),\ldots,(i_r),\ldots,$

$$(k_1),(k_2),\ldots,(k_s)$$

corresponding to identical values of

$$s_{(i_1)}=s_{(i_2)} = \ldots =s_{(i_r)}; \ldots, s_{(k_1)} =s_{(k_2)}=\ldots=s_{(k_r}$$

in decreasing sequence. The corresponding eequence of rows of matrix A is suboptimal. Go to step 5.

Step 5: Stop.

As weights $w_1,w_2,\ldots,w_n$ in the rank energy algorithm values $1^3,2^3,\ldots,n^3$ were applied. In performing the above five steps of this algorithm on matrix B, only the rows of matrix A are being clustered. In order to cluster the columns of A, exactly the same steps have to be repeated for matrix A^T*A.

Kusiak [10] coded both the matching algorithm and the rank energy algorithm in fortran - V on a computer VAX-875, and has shown that, in terms of CPU time, the rank energy algorithm

is far more efficient than the matching algorithm. But the solution quality measured by an increment of the sum (∂ ϕ) was better for Bhat-Haupt algorithm.

In the present work both the methods are coded in PASCAL and run on DEC-1090 computer, the details of which are given in chapter V. From the clustered matrix, the part families are determined visually.

CHAPTER IV

INTEGRATION OF GT AND MRP

In this chapter the principles of material requirements planning (MRP) are discussed and then the proposed approach of integrating GT and MRP is discussed in detail .

4.1 Principles of MRP:

MRP is specifically geared to satisfy the basic needs of the manufacturing enviornment. In particular, account is taken of the fact that, in such a setting, inventory management is inseparable from production planning.

The principal prerequisites and assumption implied by a standard MRP system are as follows [Orlicky, 18].

A master production schedule (MPS) exists and can be stated in bill of material terms.

All inventory items are uniquely identified.

A bill of material exists at planning time.

Inventory records containing data on the status of every item are available.

Individual item lead times are known with certainty.

Every inventory item goes into and out of stock.

All the components of an assembly are needed at the time of the assembly order release.

Discrete disbursement and usage of component materials.

Process independence of manufactured items.

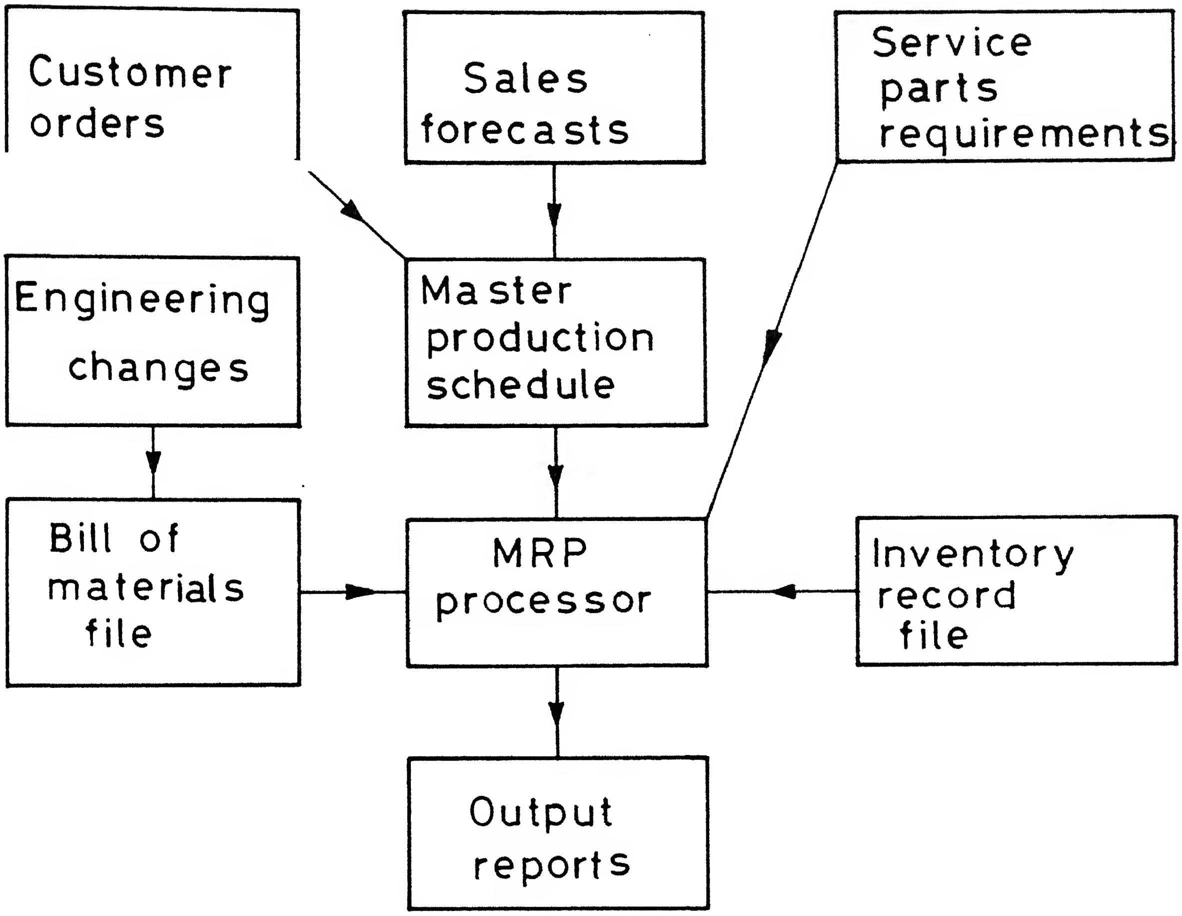


Fig.4.1 Structure of a standard material requirements planning (MRP) system

MRP converts the master production schedule (MPS) into detailed schedule for raw materials and components. The three essential inputs to MRP are

i) The MPS and other order date
ii) The bill-of-material (BOM) file, defining the product structure
iii) The inventory record file

Figure 4.1 presents a diagram showing the flow of data into the MRP processor and its conversion into useful reports.

4.2 Integration of GT and MRP:

In the proposed technique of integrating GT with MRP, the various steps performed can be described as described in the subsequent subsections.

4.2.1 Family formation using rank energy algorithm and matching algorithm:

Both of these algorithms are used to convert part-attribute matrix to a clustered output matrix.

The input to these programs are in the form of '0-1' or binary matrix. The rows of the matrix showing different parts and the columns showing various attributes. The attributes may include machining operations, various jigs and fixtures used, robot gripper types, etc. On the basis of whether a particular component needs a particular operation or any other attribute

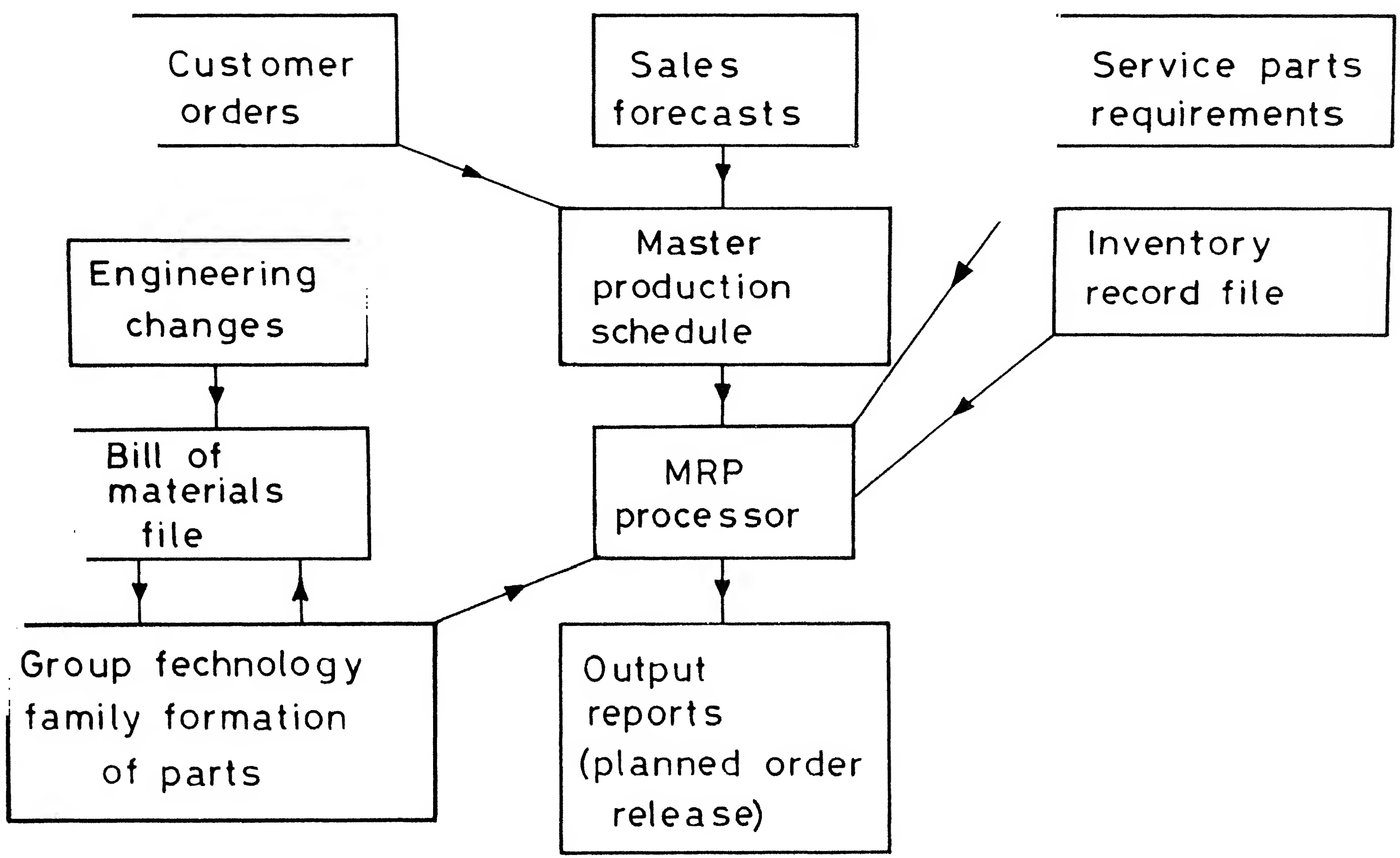


Fig. 4.2 Structure of the proposed material requirements planning.

the corresponding of the matrix for that particular part is filled up. As an example we can take drilling with drill-size less than .5 cm, if a particular component needs such an operation. We put '1' at the corresponding row and column position and if it does not need it we put zero. Similarly this is done for all the components for each operation or attribute. This part of the program is interactive, so that data can be fed from the CRT terminals by the users directly. The output from the clustering analysis models is in the form of '0-1' or binary matrices having clearly visible clustered part families. When we have all the '1's grouped in certain zones and these grouping defines the part families.

4.2.2 Material requirements planning system design:

In this part the output from the above-mentioned module is used as one of the inputs. The other major inputs are master production schedule for the end product and the detailed product structure. All the components in the product structure are coded in a level by level basis coding. The components are assigned to different levels, depending on their position in the product structure. The end product level is defined as '1' and the successive components are assigned different levels depending upon their stage of manufacture.

In the coding system used the items in level one are coded with an one digit code (e.g. 1,2, ..., 9), the second level items are coded with two digit codes which contains its parent item, the item where the component is needed, code at

the first digit and the second digit depends upon the position of the item. As an example a code '64' for the second level items will reveal that the component '64' is needed for product '6' and it is the '4'th component going into product '6'. Similarly other level components are also coded.

The above described coding system has certain advantages and disadvantages as well. The advantages are:

a) The whole product structure history of a component can be easily traced looking at the code of that component. e.g. a component having code '432115' has got the following hierarchy in production. The product '4' is the end item finally needing this component. The component is needed intermediately by several other components or subassemblies, '43211' component is the direct parent component of this part. The part '43211' is again needed for the component or subassembly '4321', and this way it continues upto the end product '4'.

b) The level of a particular component is easily obtained from the code depending upon the numbers of digits in the code. As in the previous example the six digit code shows that the part is needed at the level six computations.

c) The handling of level data for different components, becomes very easy in this type of an integer coding system.

The major disadvantage of this system of coding is it can't accomodate more than nine components under same parent.

As the repitition of same code in different levels takes place in such a case.

To solve this problem another coding method is discussed in the appendix A,which can accomodate a much wider horizon of part variety.

The lead time for each of the components are also given as input. The production cost per item is another input to the program.

The MRP program computes how many of each component and raw material are needed by 'exploding' the end product requirements into successively lower levels in the product structure. There are several factors that must be considered in the MRP parts and materials explosion. First, quantities of some of the components and subassemblies may already be in stock or on order. Hence to get the net requirements to meet the MPS, the quantities that are in inventory or scheduled for delivery in the near future must be subtracted from the gross requirements. A second factor is the effect of lead times: ordering lead times and manufacturing lead times. The due dates for assemblies, sub-assemblies and components must be offset by their manufacturing lead times so as to meet the MPS for the end products. A third factor,that complicates MRP is common use items. Usually with every possibilities there will be some components and many raw materials common to several products.

In the present work, 'lot for lot', ordering technique is followed for components in the levels lower than the basic level items or raw materials. For the basic level items

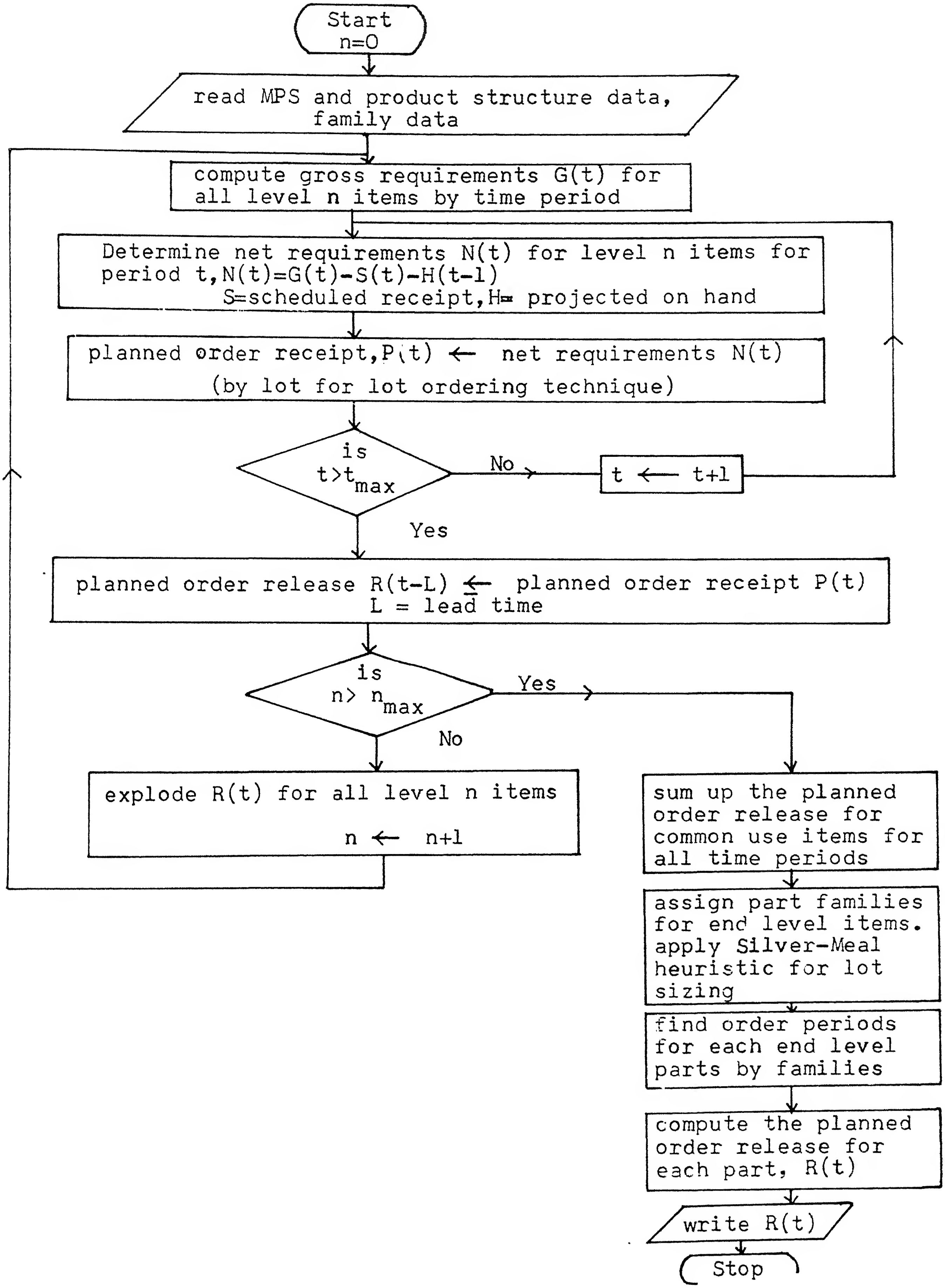


Fig. 4.3 Software Configuration for the proposed method.

or raw materials. For the basic level items lot sizing is done by a new approach, discussed latter, On the basis ordering by lot, the net requirements for different items for different periods are computed. Now these net requirements are converted into scheduled recipts, which are offset by manufacturing lead times to get the planned order releases. The net requirements for each of the common use items are summed up and combined into a single net requirement for the item for different periods.

4.2.3 Lot sizing using Silver-Meal heuristics and part families:

For the end level components or raw materials the lot sizing is done on the basis of Silver-Meal heuristics , which is described as follows:

Silver and Meal have developed a simple variation of the basic economic order quantity (EOQ) based lot sizing technique The Silver-Meal heuristic is a recommended approach for a significantly varying demand pattern.

The heuristic selects the replenishment quantity so as to replicate a property, namely, ' total relevant costs per unit time for the duration of the replenishment quantity are minimized'. If a replenishment arrives at the beginning of the first period and it covers requirements through the Tth period, then the criterion function can be given as follows:

$$\frac{(\text{set-up cost}) + (\text{Total carrying costs to end of period } T)}{T}$$

The Silver- Meal heuristic is very straight forward and is specially suitable for demand patterns, varying in nature, that do not have a clearly defined end point in the near future. Hence it is quite suitable for MRP systems.

In the present work all the end level components (or raw materials) are grouped into part families using the algorithms already mentioned in chapter III. The net requirements for each of these items are also computed, taking common use items into consideration. Now a modified version of Silver-Meal heuristic is used to find the lot sizes for each of the families instead of individual components.

If there are three components in a family having net requirements for different periods as shown in the Fig.4.4 . The computations are carried out as follows

	Q_{11}	Q_{12}	Q_{13}	Q_{14}	Product 1 Production cost-C_1 holding cost -h_1
	Q_{21}	Q_{22}	Q_{23}	Q_{24}	Product 2 Production cost-C_2 holding cost -h_2
	Q_{31}	Q_{32}	Q_{33}	Q_{34}	Product 3 production cost-C_3 holding cost -h_3
Periods	1	2	3	4	

Set-up cost for the family = A

Fig.4.4

Here we consider the set up cost to be dependent entirely on the family constituting the parts considered.

Let the relevant costs associated with a replenishment that lasts for T periods be denoted by TRC (T). In the Silver-Meal heuristic, a proper T is selected to minimize the total costs per unit time TRCUT (T) where

$$TRCUT\ (T) = \frac{TRC(T)}{T} = \frac{A\text{+Carrying costs +production costs}}{T}$$

If $T = 1$, there are no carrying costs, that is

$$TRCUT(1) = A + C_1(Q_{11}) + C_2(Q_{21}) + C_3(Q_{31})$$

For two consecutive time periods we have

$$TRCUT\ (2) = \frac{A+C_1(Q_{11}+Q_{12})+C_2(Q_{21}+Q_{22})+C_3(Q_{31}+Q_{32}) + C_1(Q_{12})\ h_1+C_2(Q_{22})h_2+C_3(Q_{32})h_3}{2}$$

Similarly for three, four, etc. periods also the total relevant costs for unit periods are computed.

The basic idea of the heuristic is to evaluate TRCUT(T) for increasing values of T until, for the first time

$$TRCUT\ (T+1) > TRCUT\ (T)$$

that is the total relevant costs per unit time start increasing. When this happens the associated T is selected as the number of periods that the replenishment should cover. The correspo-nding replenishment quantity is given by the equation

$$Q = \sum_{j=1}^{T} D(j)$$

where D(j) is the net requirements for period j

Once the different order periods are computed by the above heuristic, the planned order releases for different components for different levels on the basis of the lotsizes can be obtained easily.

CHAPTER V

IMPLEMENTATION OF THE METHOD

The proposed method has been implemented on the DEC-1090 mainframe computer of I.I.T. Kanpur, using PASCAL. This chapter presents the general features of the implementation covering the details about the working of different modules.

5.1 Software Configuration:

The software configuration is shown in the flow chart (Fig. 5.1). The whole software can be broadly divided into two subsystems

i) Part family module

ii) MRP module.

These modules are described in details in the following two subsections.

5.2 Part Family Module:

The part family module clusters a part-attribute matrix to make the part families visible. This module works in two steps, first, an imput module receives data from the user interactively to generate the part attribute matrix and second, the part attribute matrix is clustered by two clustering algorithms to get part families.

In the matching algorithm, a number of procedures are used to perform the following functions.

to compute the transpose of a matrix
to multiply matrices of various sizes
to inter change two rows
to interchange two columns
etc.

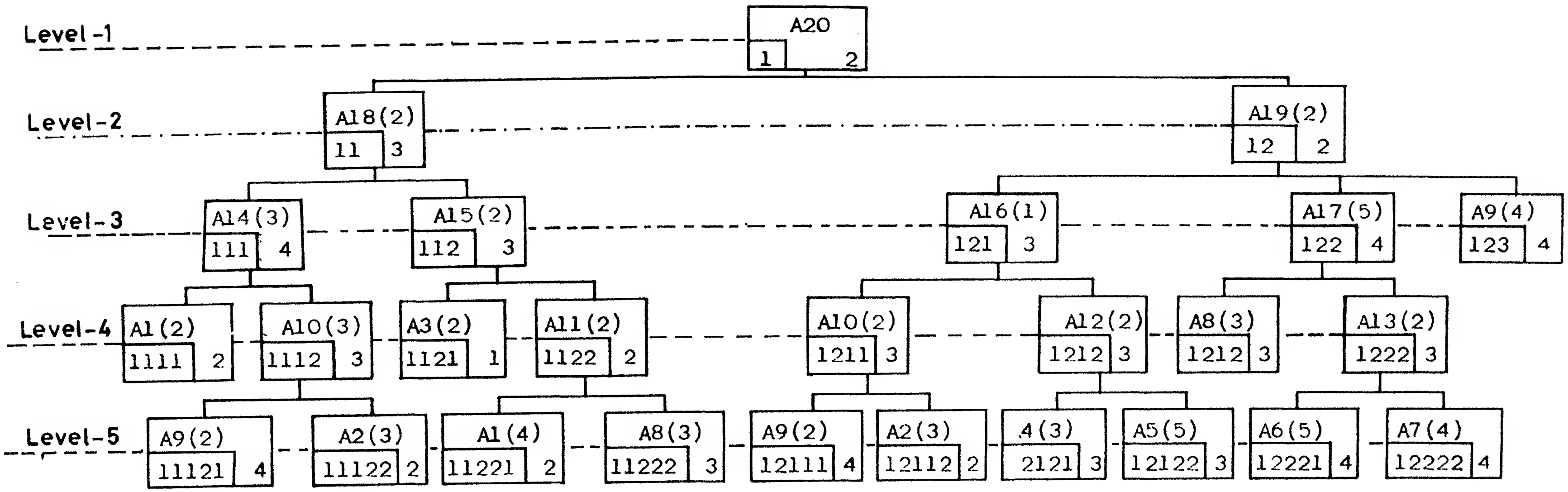
In the rank energy algorithm also various procedures are used to perform the following

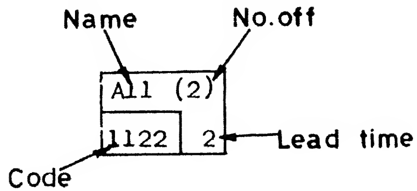
to compute the transpose of a matrix
to multiply matrices
to calculate the sum of all non-diagonal elements of each row
to calculate the sum of all elements of each row, after multiplying them by some weights
to interchange two rows
to interchange two columns
etc.

5.3 MRP Module:

The MRP module needs the master production schedule for the end products, detailed product structure and various other data for each item, e.g., lead time, part family to which the part belongs to, etc. as imput. The details of the software configuration is given in Fig. 4.3

The various demand values for the end items (MPS) is given in an array as input. The product structure and other data are fed in the form of records for each inventory item. Each of





Details of data
per item

Product structure of product
A 20 considered as an example.

Fig. 5.1 Product. structure of the model product

the records contain the following inputs.

a) the name of the item (in maximum ten letters)

b) the name in figures

c) the code of the item

d) the level of the item

e) the lead time for the item

f) the no. off.(i.e. how many of such items are needed to make one parent component)

g) family of the item

h) production cost for the item per period per item

An example of the input for item number six,in level five, having code-12221, lead time -4, no. off-5, family-2, and production cost -18 is as follows

ASIXƀ6ƀ12221ƀ5ƀ4ƀ5ƀ2ƀ18

A procedure (READINVTRY) is used to read all these above mentioned data. The set-up costs for different families are read directly from the input file.

A procedure (LEVELSEARCh) is used to find the level of each component from the code numbers for them. Another procedure (SEARCHPARENt) is used to find the parent item for higher level components by doing an integer division of the codes by ten e.g. if the itemcode is 11221 then the parentcode is (11221 div 10) or 1122.

First the net requirements for all the items are calculated, from which we get the planned order releases for the items for different periods. These planned order releases are used for computing order periods considering families and a

modified version of Silver-Meal heuristics, as already discussed in the previous chapter.

In the example considered, the product structure consists of twenty six parts in total, and the computations were made for a period ranging from 5th to 36th. The final planned order release is computed for eight periods, 5th to 12th as shown in the output module.

5.4 The Output Module:

The output of the two mentioned modules are in different forms. The output of the clustering algorithms is in the form of a '0-1' clustered matrix showing the part numbers in the extreme right column. The model input and output for the previous example described is shown in Fig. 5.2.

The output of the MRP module is in the form of planned order releases of different components for different periods. The final output consists of eight periods (5th to 12th) and all the twenty individual items (excluding the repetition for the common use items) as shown in the attached output Fig.5.3.

0	1	0	0	1	1	1	0	0	1	0	0	1	0	0	1
1	0	1	1	0	0	0	1	1	0	1	0	0	1	0	2
0	1	0	0	1	0	1	0	0	1	0	0	1	0	0	3
0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	4
0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	5
1	0	0	1	0	0	0	1	0	0	1	0	0	1	0	6
0	1	0	0	1	1	1	0	0	1	0	0	1	0	0	7
1	0	0	1	0	0	0	1	0	0	1	0	0	1	0	8
0	1	0	0	1	1	1	0	0	1	0	0	1	0	0	9

THE ABOVE MATRIX IS THE INPUT TO THE 'RANK ENERGY ALGORITHM'.

THE FOLLOWING MATRIX IS THE OUTPUT OR THE 'CLUSTERED MATRIX'.

1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	1
1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	9
1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	7
0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	5
0	1	1	0	0	0	0	0	1	1	1	1	1	0	0	2
0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	3
0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	6
1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	8
0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	4

Fig. 5.2 Input and output of the clustering algorithms.

PERIODS -->		FIVE	SIX	SEVEN	EIGHT	NINE	TEN	ELEVEN	TWELVE
ITEM NAME=	20	6	6	5	4	6	4	5	6
ITEM NAME=	18	10	8	12	8	10	12	12	12
ITEM NAME=	19	10	8	12	8	10	12	12	12
ITEM NAME=	14	24	30	36	36	36	24	30	24
ITEM NAME=	15	16	20	24	24	24	16	20	16
ITEM NAME=	16	12	8	10	12	12	12	8	10
ITEM NAME=	17	60	40	50	60	60	60	40	50
ITEM NAME=	9	224	252	216	304	224	312	960	0
ITEM NAME=	1	200	208	188	208	188	240	936	0
ITEM NAME=	10	132	96	114	88	110	88	128	98
ITEM NAME=	3	48	0	32	72	0	40	112	0
ITEM NAME=	11	18	48	32	40	32	40	32	48
ITEM NAME=	12	24	24	24	16	20	16	20	16
ITEM NAME=	8	576	0	486	0	510	0	1602	0
ITEM NAME=	13	120	120	80	100	80	100	80	120
ITEM NAME=	2	330	0	264	618	0	396	948	0
ITEM NAME=	4	108	0	108	0	120	0	336	0
ITEM NAME=	5	80	100	80	100	80	120	420	0
ITEM NAME=	6	500	400	500	1000	0	400	1700	0
ITEM NAME=	7	400	320	400	320	480	320	1600	0

Fig 5.3 output of the M R P Module.

CHAPTER VI

SUMMARY

6.1 Conclusions:

In the present work an attempt has been made to integrate several inherent benefits of GT in MRP. Two efficient algorithms are used to cluster the part-attribute matrices to get part families. These part families are then integrated in MRP computations using a modified Silver-Meal heuristics for lot sizing.

The present work can be summed up in the following conclusions.

(i) The method used in the present work can successfully reduce the set up costs for each member of different families, as the set up cost is shered by all the members of a certain family.

(ii) In the proposed technique, the various manufacturing data, as well as other data, are handled together for all the parts in a family, hence the sheer magnitude of data to be handled in MRP computations can be reduced by a significant amount.

(iii) The software will have a very useful role in batch production enviornment of modern manufacturing processes, as an efficient implementation of this method can significantly economize various costs.

The proposed technique can be improved in various directions as pointed out in the following section.

6.2 Pointers to Further Improvement:

In the present approach there are several scopes for improvement.

In the present work the ordering of the items having levels lower than the end level is made by lot for lot ordering technique, i.e., the gross requirement is the same as the planned order releases with lead time adjustments. Instead of this an efficient lot sizing algorithm can easily be applied for these components also. This will lead into more efficiency of the system.

In the part family formation module the families of parts are visually read from the clustered output matrix and then again fed into the MRP system. This part can be made automatic by finding some suitable algorithm for reading the part families directly from the clustered matrix.

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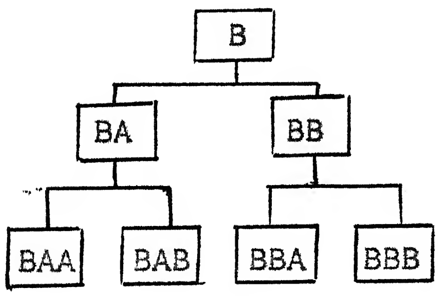
APPENDIX A

AN ALPHABETIC CODING SYSTEM

In the discrete batch type of production, a distinct identification or coding of each and every component is essential. One of the coding methods already used in the present work has got certain limitations. Here another coding system is described which is more versatile and useful.

In this coding system parts are coded by letters (alphabetic) depending on their position in the product structure. An example is as follows.



Each product code consists of its parent item's code with an increment by one letter to ensure its identity.

The main advantage of this coding system is, here a wide range of items (upto 26 in number) can be allowed under same parent item.

APPENDIX B

SOME USEFUL INSTRUCTIONS FOR USING THE SYSTEM

* The input module for part family programmes:

  As the program is executed, the following questions will be displayed on the terminal successively.

  PART NO - ?

  after the part number (one number) is supplied, the following que question is asked

  ATTRIBUTE NO. 1 - ? (Y/N)

  If the referred attribute is adequate, 'Y' should be typed, else 'N' should be typed. Similarly after completing all attribute values, it restarts with the next operation.

* The part family module:- In this module the input is given in the form of a part attribute matrix (output from input module above). As the program is executed a clustered matrix is generated as the output. The part families are to be noted from this clustered matrix.

* The MRP module Here the input is to be given in the form of records for each item as is already shown in the text (Chapter 4). The master production schedule and setup cost per family data are to be supplied separately. On execution, the planned order releases are generated as output. In this module one important factor is the proper coding of all the components as described in the text.

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This book is to be returned on the date last stamped.

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